# NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

## SUBMARINE BASE, GROTON, CONN.

REPORT NUMBER 990

DESIRABLE CHARACTERISTICS OF UNDERWATER LIGHTS
FOR HELICOPTER ESCAPE HATCHES

by

S. M. Luria, B. L. Ryack and D. F. Neri

Study conducted under contract with the
Naval Air Development Systems Command
Task N62269-82/WR/00232

and

Naval Medical Research and Development Command

Released by:

W. C. Milroy, CAPT, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

22 September 1982

# DESIRABLE CHARACTERISTICS OF UNDERWATER LIGHTS
# FOR HELICOPTER ESCAPE HATCHES


by

S. M. Luria, Ph.D.

Bernard L. Ryack, Ph.D.

David F. Neri, B.A.



NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
REPORT NUMBER 990

Naval Medical Research and Development Command
and
Naval Air Development Center, Warminster, PA 18974

Approved and Released by

W. C. MILROY, CAPT, MC, USN
Commanding Officer
NAVSUBMEDRSCHLAB

## SUMMARY PAGE

### THE PROBLEM

To specify the characteristics of lights to be installed around the emergency escape hatches of helicopters to provide for optimal visibility under water.

### FINDINGS

The optimal arrangement of lights around helicopter escape hatches, the range of intensities required, the effects of viewing angle and the dimensions of the lights on visibility, and the effects of variations in the electrical power supplied to electro-luminescent panels, have been determined.

### APPLICATION

These findings are pertinent to the setting up of specifications for lighting for helicopter escape hatches.

## ADMINISTRATIVE INFORMATION

This research was conducted under contract with Naval Air Development Systems Command, Task N62269-82/WR/00232. It was submitted for review on 27 Aug 1982, approved for publication on 22 Sep 1982 and designated as NavSubMedRschLab Rep. No. 990.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

## ABSTRACT

To specify the desirable characteristics of lighting around helicopter escape hatches which must be visible under water, tests were carried out of several types of lights. The optimal arrangement of lights around the hatch, their minimum and maximum intensity, the effects of viewing angle on their visibility, the effects of the dimensions of the lights, and the variations in the intensity of the electro-luminescent panels with changes in the power supplied were determined. Suggestions for lighting specifications are given.

A recent survey of nearly 250 competitive canoeists revealed that they regard capsizing in cold water with great concern.[1] Despite their extensive training for such an eventuality, 21% of those who had experienced capsize confessed to "extreme alarm," and 79% admitted to being concerned. Sixty-two percent reported visual difficulties, dizziness, and disorientation. How much more serious must be the problems for untrained and inexperienced individuals!

## INTRODUCTION

When a helicopter is forced to make an emergency landing in the water, the weight of the engine on top of the fuselage tends to invert the aircraft as it sinks. Among other problems, this may produce visual difficulties and disorientation for the occupants and add to the difficulty in finding an escape hatch. As was demonstrated in a preliminary study,[2] it would be of great help if the escape hatches were illuminated. In a previous study we measured the threshold intensity of underwater lights for observers in different stages of adaptation and in water of different turbidities.[3] We have also made a preliminary comparison of the effectiveness of four types of underwater lights.[4]

Despite these specific studies and a considerable general body of literature,[5] several questions remained unanswered. One has to do with the optimal configuration of lights around the escape hatch. It is important to know which side of the hatch is the top, because the release mechanism to open the hatch will be at a certain location; knowing the orientation of the hatch makes it easier to find the release. If an individual is disoriented because the helicopter has inverted under water, an arrangement of lights around the hatch that indicates which side is the top would be of great benefit.

Another question is whether or not there is a maximum light intensity which should not be exceeded. Concern has centered exclusively around the determination of the minimum light level needed for detectability in water of various turbidities. This is certainly the more important question, but in our comparison of underwater lights,[4] there was some indication that when lights of too great an intensity are installed in a small area, observers may become confused as to the location of the lights. Thus, just as the minimum necessary light level is a function of, among other things, the turbidity of the water, it is also possible that the degree of disorientation caused by very bright lights varies with the turbidity.

Another question has to do with the effect of viewing angle on the visibility of the kinds of lights which are being considered for installation. Further, does the shape of the light affect its visibility? Would it be more effective, for example, to have for the same cost, a short wide light or a long thin light? Finally, to be legibile under water, what size letters are required for any instructions which are printed on the hatches? The experiments reported in this paper bear on these questions.

## GENERAL METHODS

The experiments were carried out in an above-ground swimming pool, 12 x 21 x 4 ft deep. The subject was positioned near one end of the pool, and the lights were presented at six locations around the perimeter of the pool, 8, 10, and 14 feet from the subject (see Fig. 1). On a Boeing-Vertol V-107 helicopter troop carrier, the farthest distance from an escape hatch at which a passenger sits is about 12 ft.

Water Turbidity - Four levels of turbidity were produced during these experiments. At our lowest turbidity, a large black object was visible at a distance of about 14 to 15 ft (4.5 m) in sunlight to an observer wearing a facemask. According to Duntley's rule-of-thumb,[6] the distance in meters that such an object can be seen is equal to about $4/\alpha$; $\alpha$ is the attenuation coefficient of the water expressed in natural log units per meter. Thus, for a visibility distance of 4.5 m, $\alpha$ is about 0.9. In our moderately turbid condition the object could be seen at a distance of about 2.6 m ($\alpha \sim 1.5$). In the turbid condition, the visibility distance was about 1.6 ($\alpha \sim 2.5$). In addition, some measurements were taken at an even higher turbidity, with $\alpha \sim 3.0$. The coefficients of turbidity should be related to natural bodies of water. In very clear water, $\alpha$ is about 0.1. In the ocean near the coast, $\alpha$ may increase to about 0.5. As harbors are approached, $\alpha$ will rise to about 1.5 and in harbors and turbid rivers one would expect to find $\alpha = 2.5$ or higher.

The turbidity was controlled by adding corn starch to the water. It was adjusted about three hours before the experiment began, before sunset.

Lights - Several different lights were used in the various experiments. Their luminance was measured with a Spectra Pritchard photometer Model 1970-PR, manufactured by Photo Research Corp., Division of Kollmorgen.

(1) The "Bug-Diver 400 High Intensity Light" manufactured by the Darrell-Allen Corp. This is a hand-held light which gives out a high intensity (4,000 to 5,000 fL) collimated beam of light.

(2) The Cyalume "Lightstick" luminescent chemical illumination manufactured by American Cyanamid Co. When initiated, it produces about 150 fL; this drops within 10 minutes to about 60 fL and declines steadily thereafter to about 20 fL after two hours.

(3) Electro-luminescent panels manufactured by several companies. Some were flat panels with shiny surfaces; others were flat panels with rough, diffusing surfaces; some had sharply convex surfaces. Their maximum intensity was about 120 fL.

(4) Tritium lights - Lights produced by radioactive tritium. Their maximum intensity was about 1.5 fL.

Subjects - The subjects were staff members and enlisted men at NSMRL, as well as engineers from the Naval Air Development Center and private consulting companies associated with the research project. Different groups of individuals served as subjects in the various experiments. There were two to three subjects in each experiment.

## CONFIGURATION OF LIGHTS

A basic question was, how should the lights be arranged around the hatch? For example, should the hatch be completely outlined, or should there be a light only on one side, etc.? Three arrangements (or "configurations") considered as being among the most feasible for installation from many possible configurations were selected for testing. These are shown in Fig. 2. In Configuration I, the top and sides of the hatch are bordered with light; the bottom of the hatch is illuminated with just a small light. In Configuration II, only the top and sides are illuminated. In Configuration III, the top is illuminated along its full length, but there are only short lights on the sides.

As noted above, the reason for testing various configurations of lights is that it is generally beneficial to know which sides of the escape hatch is "up", because the release handle will be in a certain location. If the helicopter is inverted and the occupants are disoriented, they may find the hatch and yet be confused as to where the release is.

In this experiment, the goals were to determine which configuration allowed the subjects to judge most quickly which side of the hatch was the top, and, second, if the three configurations of lights showed any visibility difference at the three distances.

### Method

Three frames were constructed which were approximately the size of the escape hatches on the Boeing-Vertol V-107 helicopter (Fig. 3). Lights could be attached to these frames in the various configurations. Before the session began, the subjects were clear as to which side of the hatch was the top. With the exception noted below, the three frames were immersed with one frame closer to the subject than the others. To test the subject's ability to discriminate relative distance and to test the visibility of the configurations, the subject was first required to point as quickly as possible to the nearest frame (target frame). Then, to determine if he could judge which side of the hatch was up, he was instructed to indicate the top of the configurations immediately after pointing to the nearest frame. The locations of the frames were counterbalanced so that the nearest frame was found an equal number of times at the near, middle, and far distance. (Therefore, on a certain number of trials only one frame was immersed at the farthest distance.) Moreover, the orientation of the target frame was counterbalanced so that the "top" was presented an equal number of times in each of the four possible positions, while the orientation of the other frames was randomized.

Three subjects were tested. At the start of each trial, the subject knelt under the water with his eyes closed. The lights were positioned and illuminated. The experimenter signalled the subject and at the same time started a "lap-time" stopwatch. The times at which the subject pointed to the frame and the time taken to indicate its orientation were both recorded.

Two different types of lights were tested, electro-luminescent (EL) panels and chemical lights. The

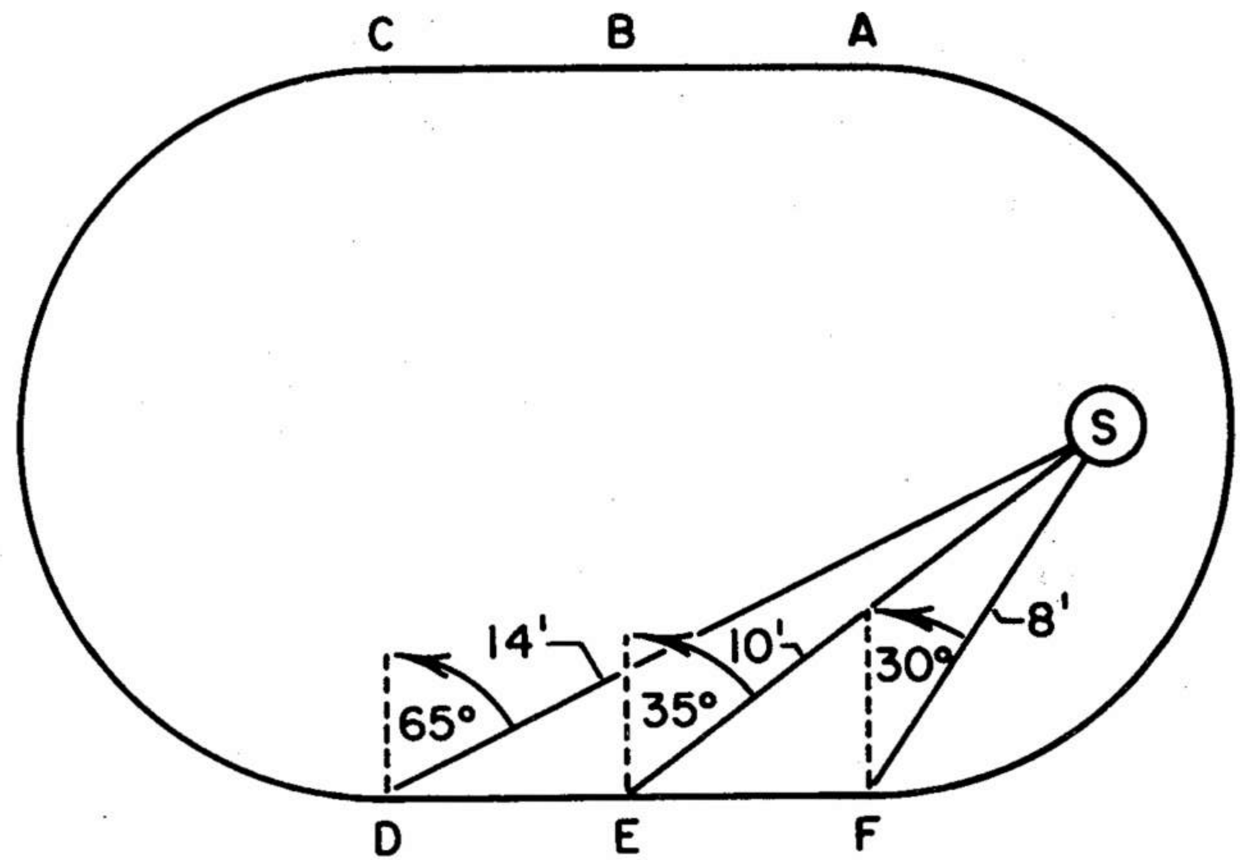


Fig. 1. Diagram of the experimental pool. The subjects were usually positioned at S. Lights were positioned at A - F, at distances of 8 to 14 ft. Since the lights were perpendicular to the wall of the pool, the angle from the light to the subject varied from about 30 to 65° from the normal.

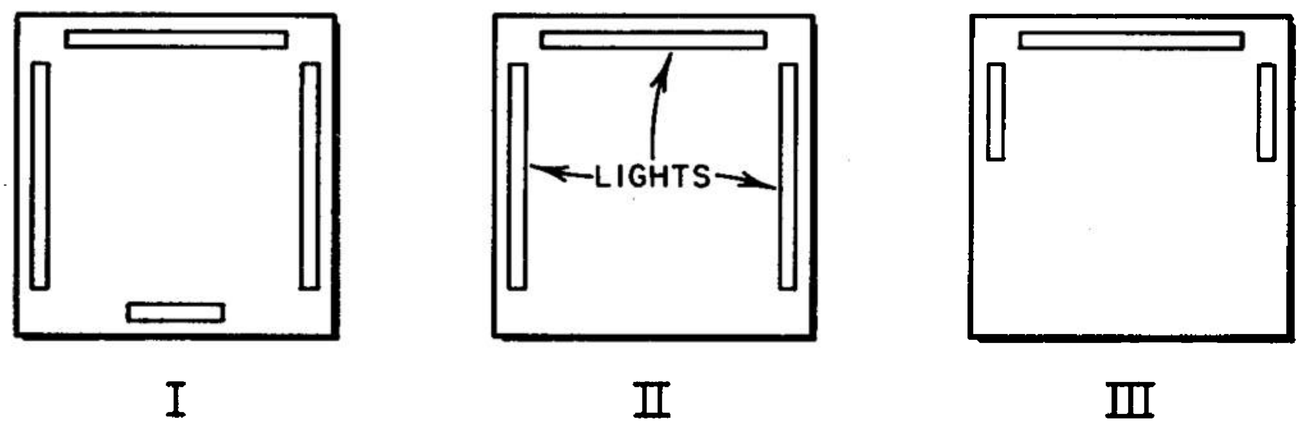


Fig. 2. The three basic configurations of the light arrangements tested in this study. "Top" is at the top of all three.

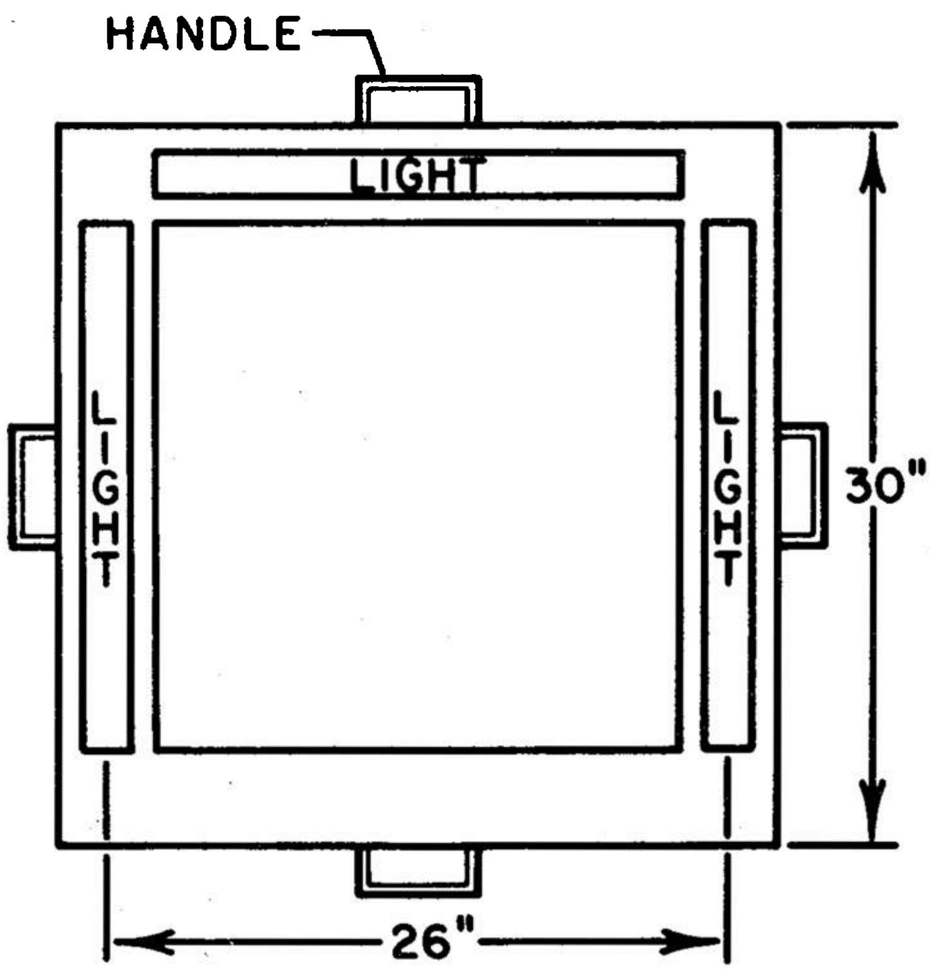


Fig. 3. The frame simulating the escape hatch to which the lights were attached.

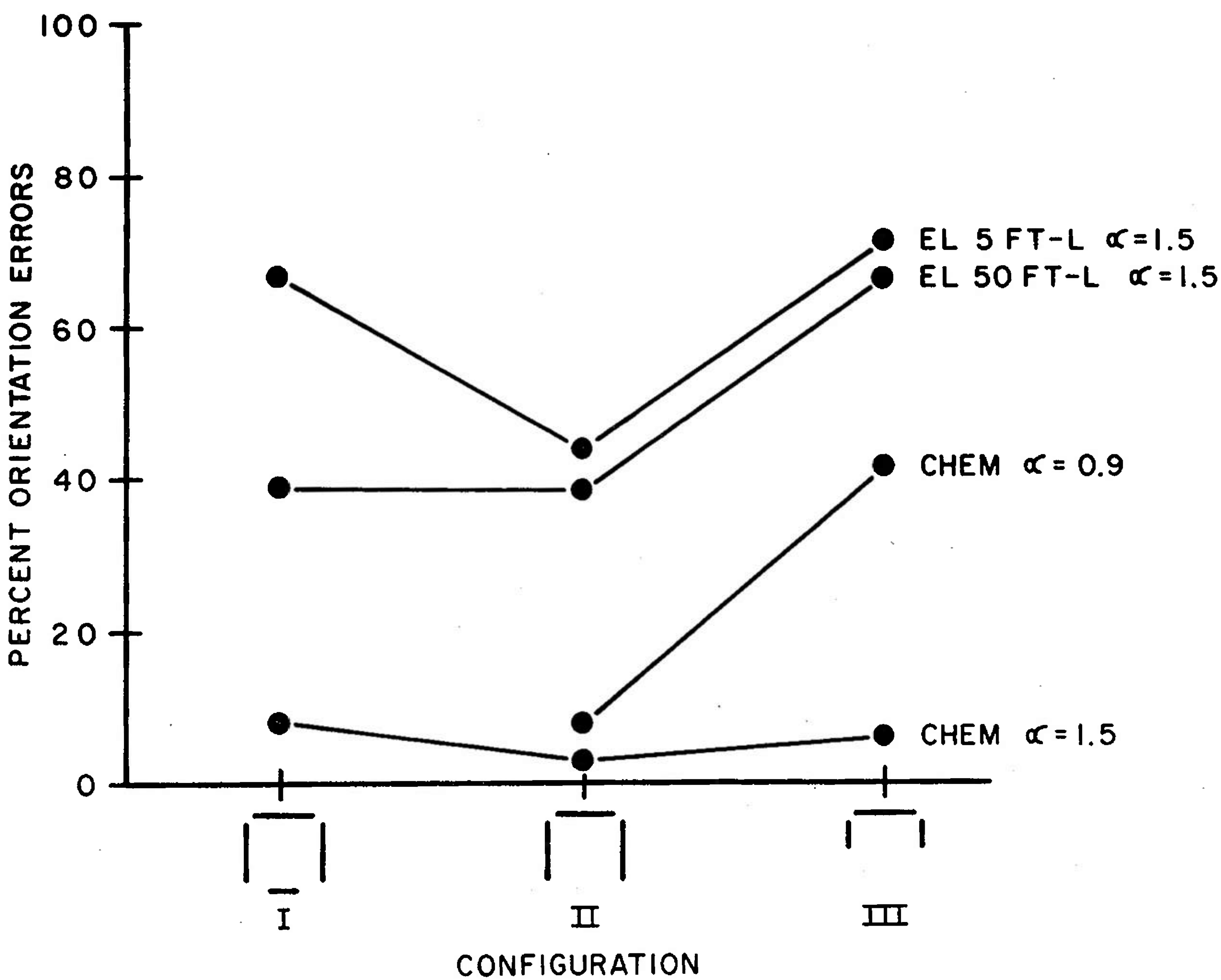


Fig. 4. Percentage of trials on which the subjects could not correctly identify the orientation of the three lighting configurations for various lights over the three distances in water of two turbidities. The chemical lights were not tested in Configuration I at a turbidity of $\alpha \sim 0.9$.

former were tested at two luminance levels, 5 and 50 fL in water of moderate turbidity ($\alpha \sim 1.5$) and the latter were tested in water of two turbidities ($\alpha \sim 0.9$ and 1.5).

## Results

Figure 4 shows, for each of the two types of lights under the different conditions, the percentage of trials in which an error was made in judging the orientation of the nearest hatch for each configuration. Typically, configuration II produced the lowest error scores.

The chemical lights were more "legible" than the EL panels, probably because they are round and not subject to any effects of viewing angle. The poorer results with the chemical lights in the less turbid water ($\alpha \sim 0.9$) than in the more turbid water ($\alpha \sim 1.5$) must be ascribed to individual differences between subjects; each of these sets of points was obtained on a different night with different subjects participating.

Table I gives the percentage of errors in judging orientation of the different configurations for the various lights at the three viewing distances. The percentage of errors, averaged for the chemical and EL panels, was least for Configuration II at each distance. The mean percentage of errors for these lights averaged over all three distances was 36% for Configuration I, 28% for Configuration II, and 47% for Configuration III. At the nearest target-distance, the ability of the subjects to see the arrangement of the lights was almost perfect; only for the dim EL panels arranged in Configuration III were there any errors. (It is likely, however, that the tritium lights, which were even dimmer, would have produced some errors if tested.) At the farthest distance, on the other hand, only the configuration of the chemical lights could be perceived. It appears that the visibility of the lighting arrangement is improved both by increased intensity and by three-dimensional lights. The chemical lights, which were somewhat dimmer than the more intense EL panels, were nevertheless more visible, presumably because they were not flat panels.

The times taken to judge the correct orientation of the configurations for the various lights are given in Table II. Although there were differences in the number of errors made in responding to the different configurations, there were no great differences in the mean times taken to make the correct judgments of orientation for the various configurations; if the orientation could be seen at all, it was seen equally fast whatever the configuration. There was, however, a clear tendency for the reaction times to increase as the lights were farther away.

This procedure was repeated at an increased turbidity ($\alpha \sim 2.5$) using long, narrow EL panels (width = 3/8 inch; length = 18 inches) to outline the top and the sides of the hatch and a 2 x 2 inch panel to illuminate a handle and indicate the bottom of the hatch (Configuration I). Once again there were no appreciable differences in reaction times between the two configurations; but as shown in Fig. 5, the percentage of errors in identifying the orientation was greater with Configuration I than when the 2 x 2 EL was omitted (Configuration II).

Table I. The percent of errors in judging orientation of the different configurations of various lights at the three viewing distances ( $\alpha \sim 1.5$)

| Light | Configuration I | | | Configuration II | | | Configuration III | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8' | 10' | 14' | 8' | 10' | 14' | 8' | 10' | 14' |
| Chemical | 0 | 3 | 6 | 0 | 0 | 3 | 0 | 0 | 6 |
| Tritium | - | - | - | 0 | 100 | 100 | - | - | - |
| Narrow EL (50 fL) | 0 | 17 | 100 | 0 | 17 | 100 | 0 | 100 | 100 |
| Narrow EL (5 fL) | 0 | 100 | 100 | 0 | 33 | 100 | 33 | 83 | 100 |

- not done

Table II. Mean time (sec) taken to judge the correct orientation of the different configurations of various lights at the three viewing distances

| Light | Configuration I | | | Configuration II | | | Configuration III | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8' | 10' | 14' | 8' | 10' | 14' | 8' | 10' | 14' |
| Chemical | 4.82 | 6.16 | 5.46 | 2.77 | 5.03 | 5.36 | 2.94 | 4.08 | 5.88 |
| Tritium | - | - | - | 3.56 | * | * | - | - | - |
| Narrow EL (50 fL) | 2.60 | 4.47 | * | 3.12 | 3.66 | * | 2.60 | * | * |
| Narrow EL (5 fL) | 2.68 | * | * | 2.57 | 2.00 | * | 3.32 | 5.10 | * |

- not done
* Orientation could not be perceived.

## INTENSITY RANGE

### Minimum Intensity

Extensive measurements have been made of the threshold intensity for subjects at various adaptation levels in water of different turbidities.[3] These measurements were made, however, with relatively small single lights. It was, therefore, decided to measure threshold intensity for a set of the much longer EL lights arranged into a hatch configuration.

#### Method

The frames were randomly placed in the water at the various positions, and the intensity of the narrow EL panels were slowly increased until the subject signalled that he could detect the light. Several measurements were made at each of the target-distances for two subjects.

For this experiment, the turbidity was increased to an $\alpha$ of 3.0. On the basis of the records of helicopter crashes during the last 20 years,[7] it is unlikely that crashes will occur in water of greater turbidity than this. Thus, lights of this threshold intensity will probably be visible, although as Smith et al.[3] pointed out, we have no information on how turbid the water becomes inside a submerged helicopter as a result of oil spills, etc.

#### Results

The mean thresholds are shown in Fig. 6. At the near distance of 8 ft, a mean intensity of only 2 fL was required despite the increased turbidity. This increased to 8 fL at a target distance of 10 ft and to 20 fL at 14 ft.

These threshold values are not what would be expected on the basis of Duntley's rule-of-thumb for visibility or the amount of light transmitted through water of these turbidities. But it is important to keep in mind that Duntley's rule is formulated for light-adapted divers wearing facemasks, whereas these results were obtained with dark-adapted divers without facemasks. And in relatively turbid water the observer does not see a clear image of the lights but is, rather, looking for a vague cloud of light more or less out of the corner of his eye. Any anomalous aspects of the results are probably due to these unusual conditions.

### Maximum Intensity

There are some reasons for considering the possibility that the intensity of the escape-lights should not be made too high despite an inclination to assume that the brighter the better. In turbid water, a bright light could produce a large cloud of light which could make it difficult to localize the light. We, therefore, measured localization errors to lights of various intensities in turbid water ($\alpha \sim 2.5$).

#### Method

To achieve high intensities, the "Bug Diver High Intensity Light" was used. The same general procedure was employed. Three lights were immersed so that one was closer than the other two. The subject on each trial pointed as quickly as possible to the nearest light. His pointing error was estimated. The intensity of the Bug lights was adjusted with

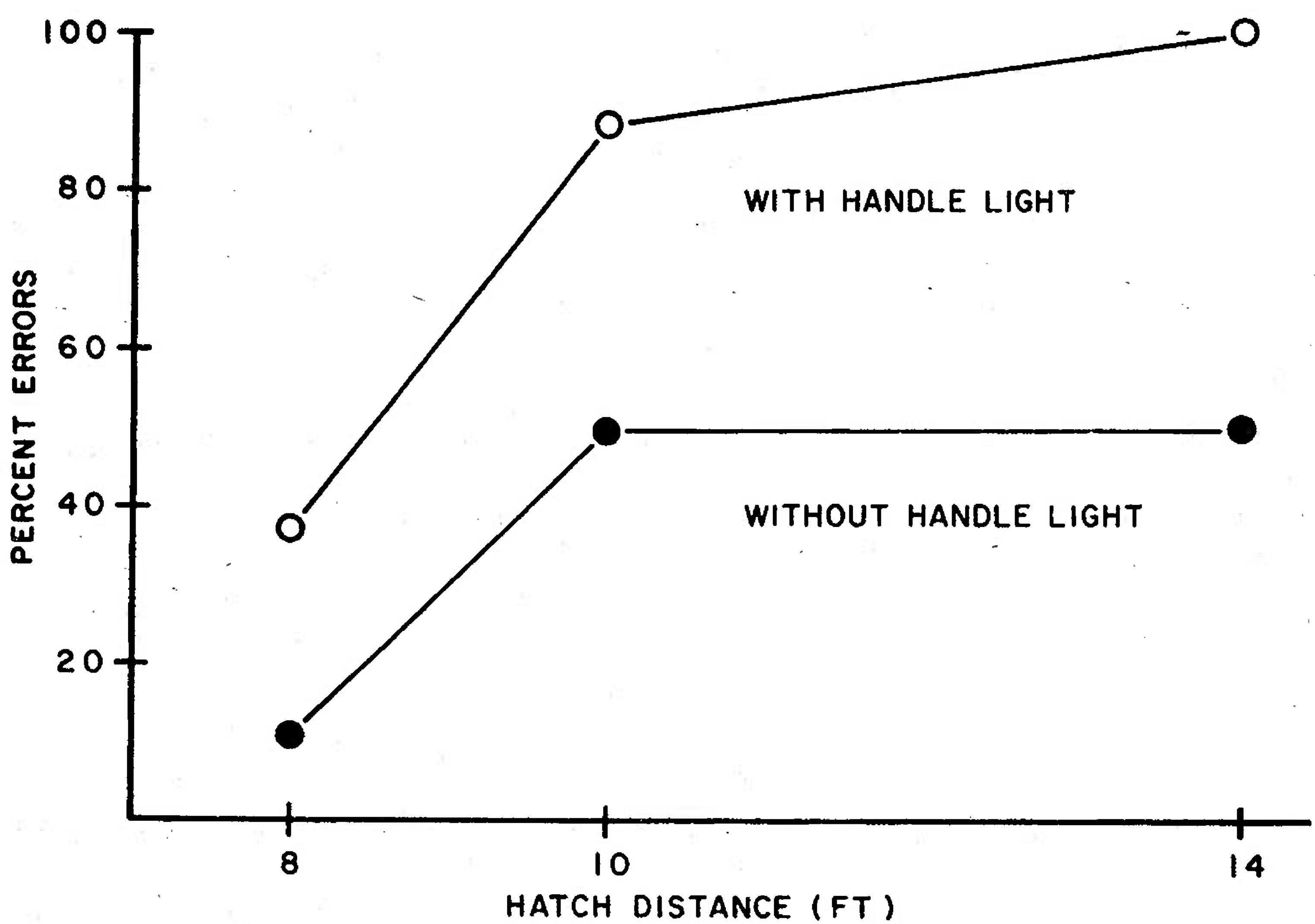


Fig. 5. Percentages of trials on which the subjects could not identify the orientation of two configurations at three distances in highly turbid water ($\alpha \sim 2.5$).

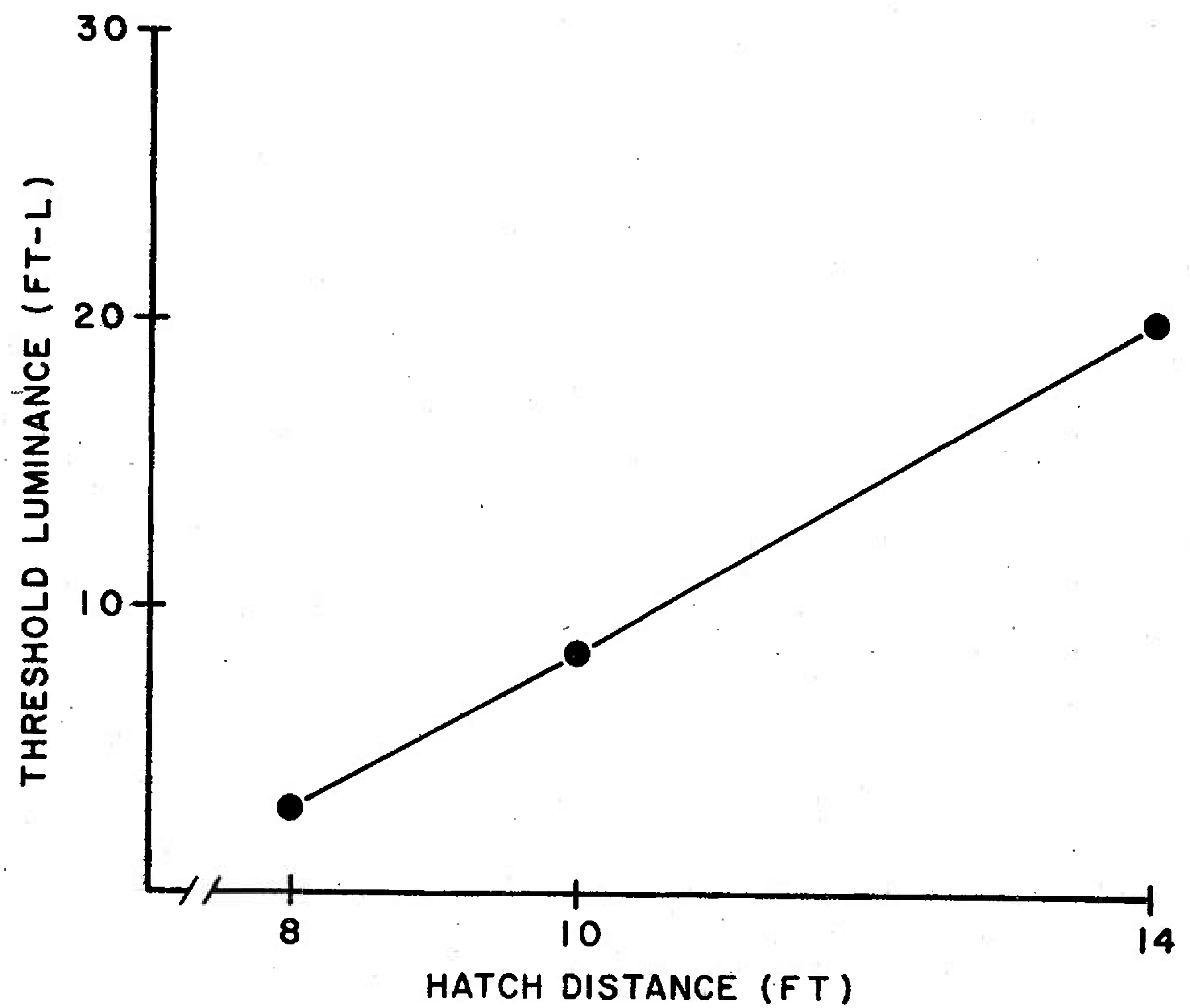


Fig. 6. Mean threshold intensity (fL) of the configurations of EL panels at different distances in highly turbid water ($\alpha \sim 3.0$).

neutral density filters.

## Results

At full intensity, about 4,500 fL, 6% of the responses showed appreciable localization errors. When the lights were dimmed to 1,500 fL, the same percentage was obtained. However, at an intensity of 200 fL, there were no large pointing errors. Since it was thought unlikely that the manufacturer would provide escape lights more intense than 200 fL, no further measurements were made.

## VIEWING ANGLE

Usually the occupant of a helicopter will not be sitting directly across from a hatch and will, therefore, not be looking directly at the hatch lights. It is important to know, then, to what extent the visibility of the lights is affected by the viewing angle.

Figure 7 shows for example, the effects of viewing angle in air. This gives the results of measuring the intensity of three different EL panels with a Spectra-Pritchard Photometer, from viewing angles of 90° (perpendicular to the panel) to 10°. Two of the panels had shiny, non-diffusing surfaces; one of these was 2 inches wide and the other was 3/8 inch wide. The third panel had a rough, diffusing surface and was one inch wide. There was little decline in luminous flux until the viewing angle was less than 30°. Interestingly, there appeared to be no difference in the rate of decrease of intensity between the shiny and the diffusing panels.

More to the point are the threshold intensities of the various lights obtained for subjects in the water. Three EL panels were tested. Two were flat and one was convex. One of the flat panels had a shiny, non-diffusing surface: the other had a rough, diffusing surface.

## Method

The panels were immersed against the side of the pool. The subject faced the darkened light at various viewing angles, tested in random order, from a distance of 8 ft. The intensity of each light was gradually increased until the subject signalled that he could see the light. Two measurements were made at each viewing angle for each of two subjects.

## Results

Figure 8 shows the threshold intensities in water of different turbidities. The flat panels exhibited some loss of visibility as the viewing angle became less direct, although in one case the loss was quite small. There was little difference between the shiny, non-diffusing panel and the panel with the diffusing surface. Not surprisingly, the convex panel showed no change whatsoever in threshold as the viewing angle changed.

It was expected that as the turbidity increased, the effects of viewing angle would decrease. The reasoning was that the increased turbidity would increase the scatter of light and facilitate its detection when the viewing angle was not direct. There is no clear indication that this happened. If there are any general conclusions to be drawn from this figure, it is that, first, a convex panel would suffer no loss of visibility with changes in viewing

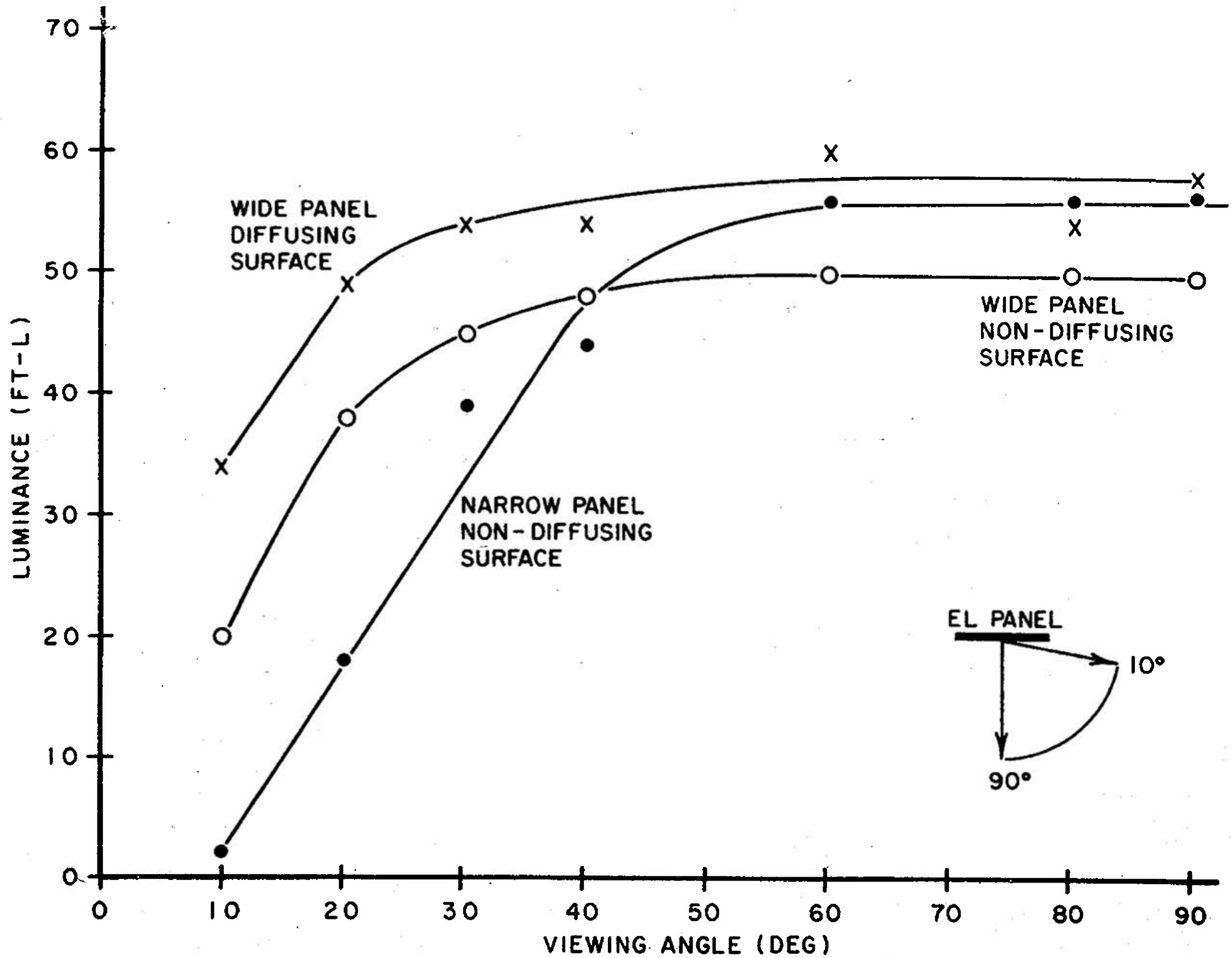


Fig. 7. Luminance of three EL panels in air with changes in viewing angle.

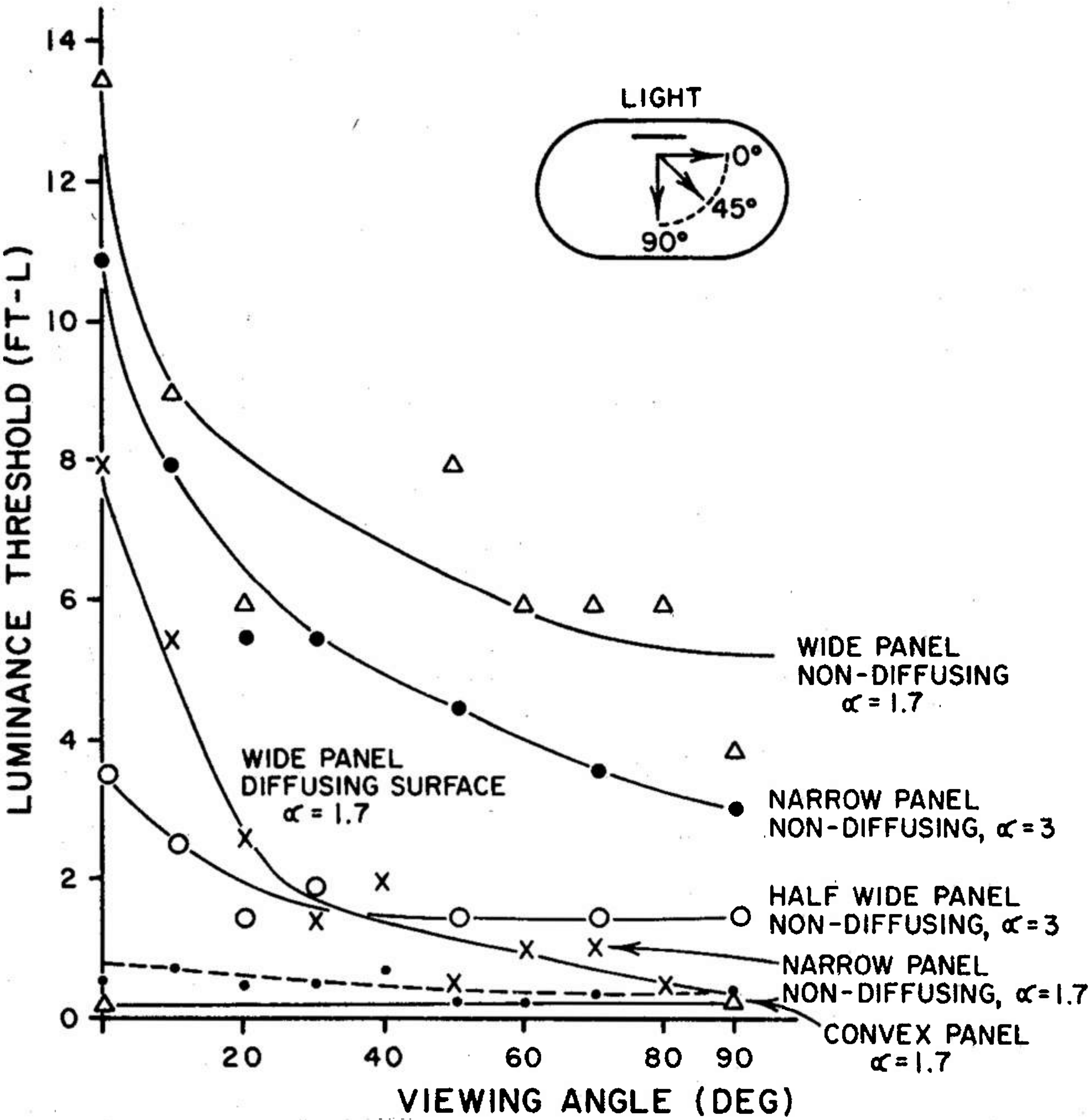


Fig. 8. Threshold intensity of various EL panels in water of various turbidities with changes in viewing angle. Viewing distance was 8 ft.

angle. Second, for flat panels it must be expected that threshold luminance will increase as the viewing angle decreases from 90° to small angles, and flat panels should not be used if they must be viewed at small angles.

## SHAPE OF LIGHTS

Electro-luminescent panels can be made in any size and shape. The power required for a panel depends on its area, and, of course, the same area can be configured in a variety of shapes. If EL panels are chosen to light the escape hatches, a basic question is whether one shape would be more easily visible than another. Would, for example, a long, thin light be more visible than a short, wide light?

### Method

To test this, two of the wider EL panels, 2 x 10 inches, were mounted end-to-end to give one light 2 x 20 inches. This light was partially masked in various ways with black tape and its threshold intensity measured in water with $\alpha \sim 2.5$. Threshold intensity was measured for both the double panel and for one panel completely exposed, one or two panels three-quarters exposed, half exposed, or one-quarter exposed. The subject was positioned 10 ft from the darkened lights and their intensity slowly increased until he signalled that he could see the light. For each light configuration, two such determinations were made for two subjects.

### Results

The results, shown in Fig. 9, indicate that shorter, wider panels are more visible than longer, thinner panels. Three comparisons among the eight thresholds lead to this conclusion. First, the 2 x 10 inch panel (A) and the 1 x 20 inch panel (C) both comprise 20 square inches of lighted surface; the former gave the lower threshold. Second, the 1 x 10 inch panel (D) and the 1/2 x 20 inch panel (E) both have 10 square inches of surface; again, the shorter, wider panel gave the lower threshold. Third, consider the 1.5 x 10 inch panel (B) and the 1 x 20 inch panel (C). In this case, the latter presents a greater area of lighted surface, 20 sq. in., than the former, 15 sq. in. Yet, the threshold for the shorter, wider panel is again lower.

## INSTRUCTION DECALS

It is customary to put decals on escape hatches giving instructions for opening the hatch. A sample of such an instruction decal is shown in Fig. 10. It measures 8 x 1.75 inches; the letters are 1/2 inch high. It is, of course, well known that an individual in the water without a facemask suffers an enormous loss of visual acuity.[8,9] To demonstrate this again, the words "push" and "pull" were written in various sizes in black on a silver metallic background and held under water at reading distance.

### Method

The words were presented to the subject at a distance of 12 inches in increasing size until he could read the word. In bright sunlight, the smallest size lettering which was legible was about 2-1/4 inches tall with a thickness of about 3/8

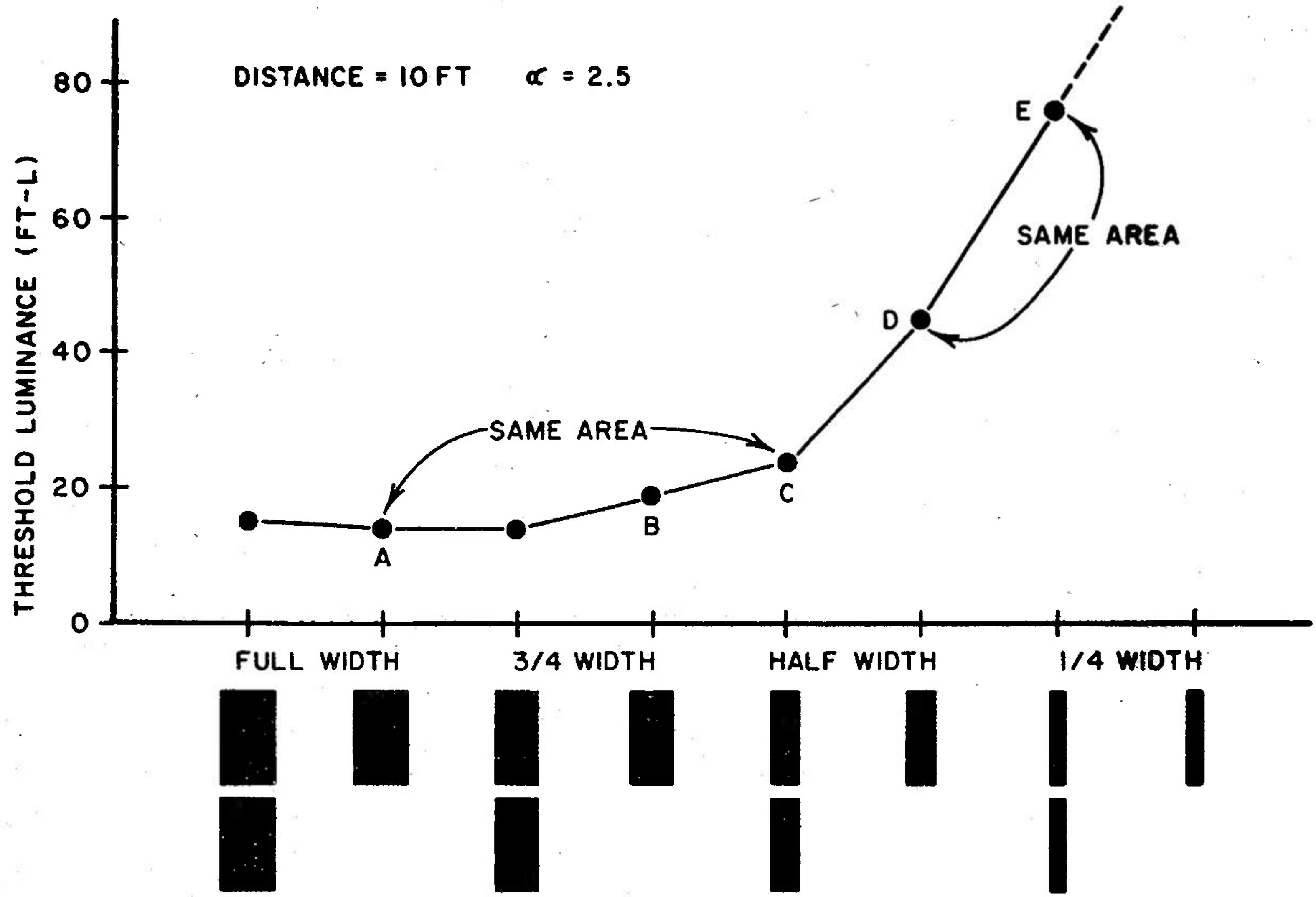


Fig. 9. Luminance thresholds for EL panels of various lengths and widths. The viewing distance was 10 ft, and $\alpha \sim 2.5$.

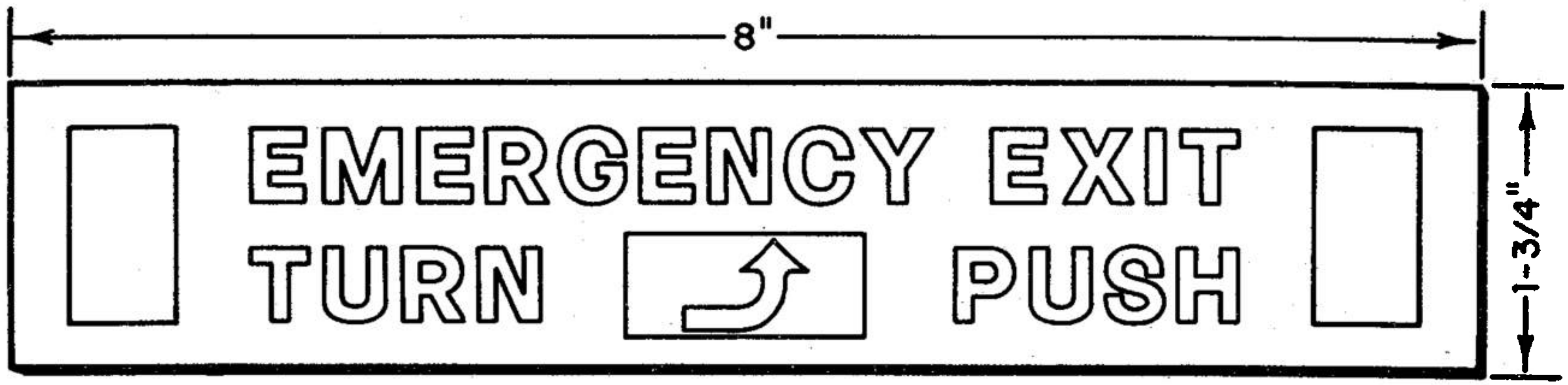


Fig. 10. An instruction decal from a helicopter emergency exit hatch.

inch.

The same procedure was carried out at night by building a plexiglas box which was partially immersed. Black cards with the words cut out in different sizes were placed against the front of the box and illuminated from behind with the high intensity bug light. Under these conditions, an even larger size of lettering was required for legibility; the smallest size letter which could be read was about 3 inches tall. It is clear that if such letter sizes are required, very little information can feasibly be presented.

EFFECTS OF VARIATIONS OF ELECTRICAL POWER

During the course of the experiments it became clear that the luminance of the EL panels varied with the size and number of panels which were wired together and with the line voltage. It may be of interest to note examples of these variations. Figure 11 shows the luminance of the 3/8 inch wide panels as the percentage of the line voltage is varied by rheostat and as the line voltage itself varies. When four of these panels are wired to the rheostat at the maximum setting of 100%, their luminance is 120 fL when the line voltage is 120 v. but only about 105 fL when the line voltage drops to 110 v., etc. As the percentage of the line voltage is decreased, the luminance decreases similarly for all line voltages.

The data in Table III show the effects of the size of the EL panels on luminance. The table shows the luminance of two sizes of panels, 3/8 x 18 inches (narrow) and 2 x 10 inches (wide), when they are illuminated simultaneously in different combinations. During these measurements, there were always 8 panels wired together. When all 8 panels were the narrow ones, the luminance of each of these panels was 120 fL at 100% of the line voltage (120 v.) and 6.7 fL at 40% of the line voltage. When one of the narrow panels was replaced by one of the wide panels, the luminance of the former decreased to 110 fL; the luminance of the wide panel was 120 fL. When two of the narrow panels were replaced with wide panels, the luminance of the former decreased further to 92 fL, and the luminance of the wide panels decreased to 110 fL, at 100% of line voltage. When there were four panels of each, the luminance of the narrow panels was only 64 fL, and that of the wide was 92 fL at 100% of line voltage. The table shows the combination-luminance relationship for both 100% and 40% of the maximum rheostat settings.

Table IV shows the luminance of the convex EL panels at various rheostat settings when either one or two such panels were illuminated from the same power supply.

DISCUSSION

To determine which arrangement of lights was best, we measured the errors in detecting which side of the hatch was the top at different distances. It was clear that when the top and sides of the hatch were outlined with lights but the bottom was left unlighted, it was easiest to identify the top at a distance. There may, however, be a reason to install a light at the bottom of the hatch: in some cases there is a release-handle there which should be illuminated. If so, we do not believe this poses a serious problem. When the observer

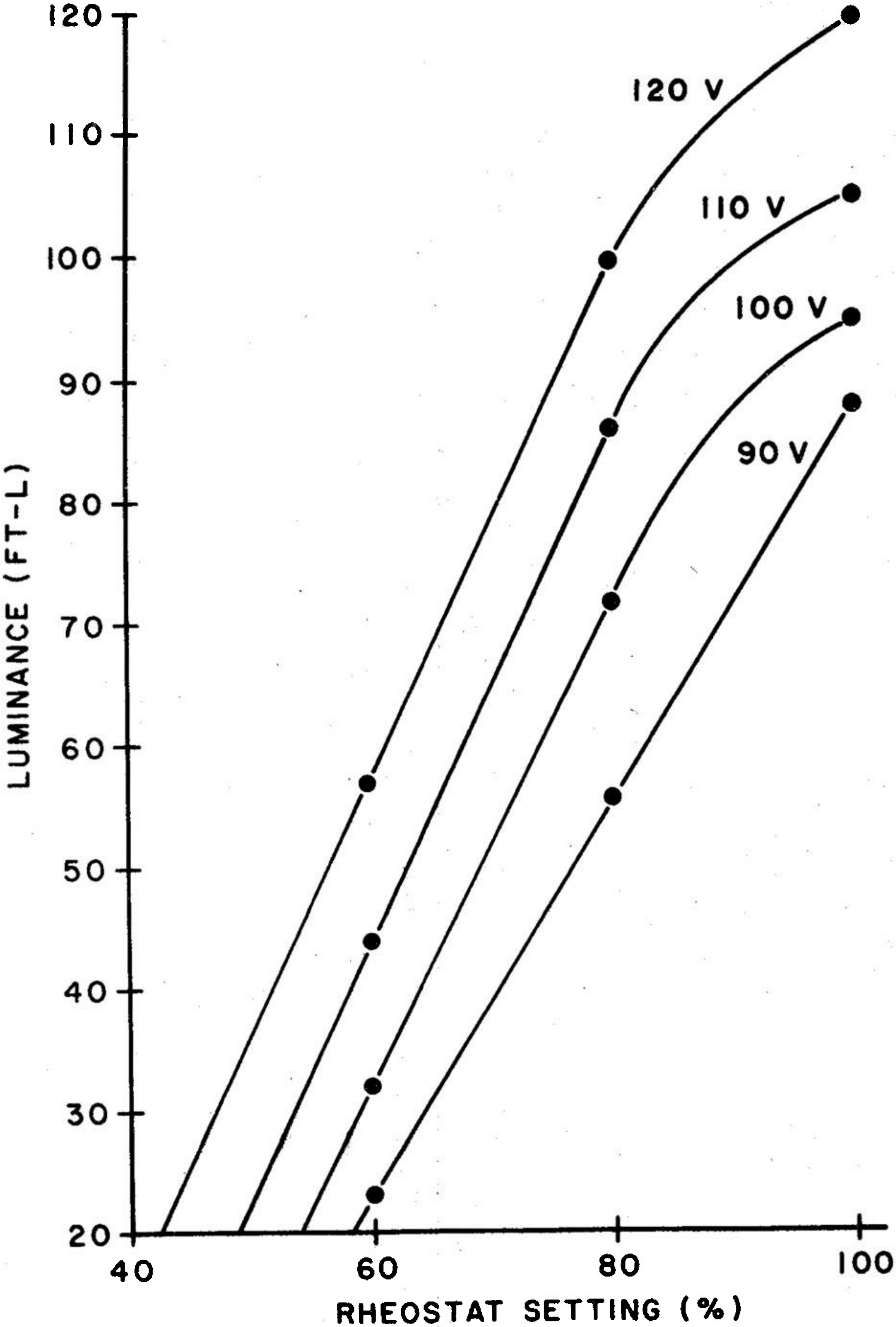


Fig. 11. Luminance of a set of four 3/8 x 18 inch EL panels as a function of the line voltage.

Table III. Luminance (fL) of wide (2 x 10 in) and narrow (x/8 x 18 in) EL panels as a function of the combinations of eight panels simultaneously illuminated

| Maximum Rheostat Setting | Number of Panels | | | Luminance | |
|---|---|---|---|---|---|
| | Wide | plus | Narrow | Wide | Narrow |
| 100% | 0 | | 8 | - | 120 |
| | 1 | | 7 | 120 | 110 |
| | 2 | | 6 | 110 | 92 |
| | 3 | | 5 | 100 | 76 |
| | 4 | | 4 | 92 | 64 |
| 40% | 0 | | 8 | - | 6.7 |
| | 1 | | 7 | 12 | 4.0 |
| | 2 | | 6 | 7 | 2.2 |
| | 3 | | 5 | 4.2 | 0.9 |
| | 4 | | 4 | 2.5 | 0.5 |

Table IV. Luminance (fL) of convex EL panels at various rheostat settings when either one or two panels are powered by the same power supply

| Percent of maximum rheostat setting | One light | Two lights |
|---|---|---|
| 40 | 1.7 | 0.2 |
| 45 | 3.9 | 1.5 |
| 55 | 10.0 | 4.5 |
| 65 | 18.0 | 10.5 |
| 75 | 25.0 | 17.5 |
| 85 | 34.0 | 21.0 |
| 95 | 43.0 | 23.0 |
| 100 | 45.0 | 25.0 |

was close enough, he could judge which was the top of the hatch no matter which lighting arrangement was used. Obviously, in order to open the hatch the observer must be very close. Since all the lighting configurations allow the observer to locate the hatches, there is little doubt that he will be able to orient them when he is close enough. These results indicate that it is not necessary to completely outline the hatch with lights. If it is necessary, for reasons of cost or weight, to eliminate some lights such as the light along the bottom of the hatch and to reduce the length of the side-lights, that apparently can be done without danger.

The problem of maximum intensity turned out to be less serious than anticipated. It appears that much of the disorientation noted in the previous study[4] resulted from the collimated light beams from the Bud Diver Lights. None of the lights assembled into configurations for these tests was collimated, and there was much less disorientation.

The findings that the shorter, wider panel was more detectable than the longer,thinner panel of the same area is of some interest. There has been a considerable amount of research on the question of the relative identifiability of various shapes.[10] A number of studies have concluded that triangles are more easily identified than other geometric shapes. But it was difficult to predict from these results what the results of our experiment would be, because the shapes of the lights were never perceptible. We have found only two studies that bear on this problem. Wulfeck et al.[11, p.239] cite a study in which different shapes and areas were increased in luminance until the light was detectable. The investigators concluded that size, not shape, determined visibility. It appears that this was not the case in the present experiment, because the areas of the two shapes were equal, and the shorter stimulus was more detectable.

Helson and Fehrer[12] presented different black forms of equal area in front of a back-lighted ground glass screen. They determined the luminance thresholds for detection of the light, the luminance at which the subjects realized a geometric form was present, and thresholds for the accurate identification of the form. The luminance thresholds for the identification of the different forms varied by a factor of nearly four from one form to another; the thresholds for the detection of the presence of light surrounding the different forms were virtually identical. In view of the fact that in the water the different shapes could not be discriminated and the thresholds are, therefore, simply for the detection of light, we would expect no difference between the detection thresholds for the different shapes which we presented.

Yet, we did find a difference favoring the shorter stimulus. The explanation may be the one suggested by Semple et al.[10] in commenting on the results of an experiment by Hochberg et al.[13] Hochberg et al. measured visibility thresholds for different shapes of equal area and concluded that visibility was best for simple, compact,and familiar figures. Semple et al. suggested that the compact figures may have been more detectable because there was an increase in brightness over the smaller angular subtense. This seems quite possible in the present case, for we were comparing two EL panels of equal area-with one much longer than the other, the shapes were not discriminable, and we were dealing with light spread diffusely over different angular subtenses.

The loss of visibility of the lights as the angle of regard from the normal becomes greater does not seem to pose a great problem. There is no great decrease until the viewing angle is below 45°. It is not likely that the viewing angle would fall much below this. The thresholds for viewing angles of 0° were obtained with the subjects holding their heads against the side of the pool; this is not likely to occur in a normal helicopter. If the water is reasonably clear, then one of the hatch lights should be visible. In turbid water, the decrease in visibility could be a problem, but it can easily be solved by making the panels somewhat convex.

The results of the attempts to read words under water show that it is not feasible to use printed instructions in the water. The passengers of the helicopter must be given training beforehand in opening the escape hatches so that they are like the well trained soldier who can disassemble and reassemble his rifle in the dark.

The dependence of luminance on line voltage and the number of other lights powered by the same supply suggests that it may be advisable to stabilize the line voltage and perhaps have a separate power supply for each light.

ACKNOWLEDGMENTS

We gratefully acknowledge the help of many people in these experiments. Geoffry Robson, HN Don Mercado, HN Marcus Speckhahn, Dennis Schmickley, and Dr. James A. Worthey served as subjects. HM1 Eric Keslov, Robert Nelson, William Remini, Karen Robinson, William Rogers, CDR James Socks and Paul Smith assisted the experimenters.

REFERENCES

1. A. J. Bakers, Canoeists' disorientation following cold immersion. Brit. J. Sports Med. 15, 111-115, 1981.

2. B. L. Ryack, P. F. Smith, S. M. Champlin, and E. M. Noddin, The effectiveness of escape hatch illumination as an aid to egress from a submerged helicopter. NSMRL Rep. No. 857 (in preparation).

3. P. F. Smith, S. M. Luria, and B. L. Ryack, Luminance thresholds of the water-immersed eye. Aviat. Space Environ.Med. 49, 1173-1176, 1978.

4. S. M. Luria, B. L. Ryack, and D. Temple, A comparison of underwater helicopter-escape lights. Aviat. Space Environ. Med. 51, 674-679, 1980.

5. W. S. Vaughan, Jr. and J. A. S. Kinney, Human Engineering Guides to Design of Displays for Underwater Applications. Oceanautics, Inc. Annapolis, MD, Dec 1981.

6. S. Q. Duntley, Light in the sea, J. Opt. Soc. Am. 53, 214-233, 1963.

7. K. Waters, Talk presented at Helicopter Emergency Egress Lighting Program meeting, NAVAIRDEVCEN, Warminster, PA, 17 Mar 1982.

8. S. M. Luria and J. A. S. Kinney, Vision in the water without a facemask. Aviat. Space Environ. Med. 48, 1128-1131, 1975.

9. S. M. Luria and J. A. S. Kinney, Acuity-luminance function for extreme refractive error. Am. J. Optom. 47, 205-211, 1970.

10. C. A. Semple, Jr., R. J. Heapy, E. J. Conway, Jr.,and K. T. Burnette, Analysis of human factors data for electronic flight display systems. AFFDL-TR-70-174, Wright-Patterson AFB, Ohio, April 1971.

11. J. W. Wulfeck, A. Weisz, M. W. Raben, Vision in military aviation. WADC Tech. Rep. 58-399, November 1958.

12. H. Helson and E. Fehrer, The role of form in perception. Am. J. Psychol. 44, 79-102, 1932.

13. J. E. Hochberg, H. Gleitman, and P. D. Macbridge, Visual threshold as a function of simplicity of form. Am. Psychol. 3, 341-342, 1948.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

## REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER: NSMRL Report No. 990 | 2. GOVT ACCESSION NO. |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle): DESIRABLE CHARACTERISTICS OF UNDERWATER LIGHTS FOR HELICOPTER ESCAPE HATCHES | 5. TYPE OF REPORT & PERIOD COVERED: Interim Report |
| | 6. PERFORMING ORG. REPORT NUMBER: NSMRL Rep. No. 990 |
| 7. AUTHOR(s): S. M. LURIA , BERNARD L. RYACK, AND DAVID F. NERI | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, Connecticut 06349-0900 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: NAVAIRDEVSYSCOM Task N62269-82/WR/00232 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, Connecticut 06349-0900 | 12. REPORT DATE: 22 Sep 1982 |
| | 13. NUMBER OF PAGES: 25 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office): Naval Air Development Systems Command, Warminster, PA 18974 | 15. SECURITY CLASS. (of this report): Unclassified |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Helicopter egress; underwater vision; underwater lighting

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

To specify the desirable characteristics of lighting around helicopter escape hatches which must be visible under water, tests were carried out of several types of lights. The optimal arrangement of lights around the hatch, their minimum and maximum intensity, the effects of viewing angle on their visibility, the effects of the dimensions of the lights, and the variations in the intensity of the electro-luminescent panels with changes in the power supplied were determined. Suggestions for lighting specifications are given.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)